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SEISMIC DATA LABORATORY
QUARTERLY TECHNICAL SUMMARY REPORT

JULY - SEPTEMBER 1968

15 OCTOBER 1968

Prepared For

AIR FORCE TECHNICAL APPLICATIONS CENTER
Washington, D. C.

By

TELEDYNE, INC.

Under

Project VELA UNIFORM

Sponsored By

ADVANCED RESEARCH PROJECTS AGENCY
Nuclear Test Detection Office
ARPA Order No. 624

37

SEISMIC DATA LABORATORY

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ABSTRACT

This report summarizes the work done by the SDL during the period July through September 1968, and is primarily concerned with seismic research activities related to the detection and identification of nuclear explosions and earthquake phenomena. Also discussed are the support tasks and data services performed for other participants in the VELA-Uniform projects.

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I. INTRODUCTION

This quarterly report summarizes the technical work, support effort, and service tasks completed during the period July through September 1968. Current or past work is mentioned only if it relates to the present discussions.

Reviews of technical reports completed during the reporting period are contained in Section II under descriptive headings. Section III is a summary of the support and service tasks performed for in-house projects and for other VELA-Uniform participants. This report concludes with Appendix A in which are listed the organizations who received SDL data services during the period.

II. WORK COMPLETED

A. Preliminary Evaluation of NORSAR

The purpose of this study was to present a preliminary evaluation of the Norwegian Seismic Array (NORSAR). We were interested, specifically, in determining: 1) the minimum inter-sensor spacing required to produce optimum rms noise reduction by summing the array, and 2) the amount of signal loss, rms noise reduction, and signal-to-noise gain produced by beamforming the array. The basic procedures included reformating the original data, prefiltering, computing power spectra, time-shifting, and summing.

The results of the analysis of one noise sample are included here and are summarized in Figure 1. The rms noise reduction produced by summing the various combinations of subarrays is shown as a function of the corresponding average inter-sensor spacing and compared with the corresponding $N^{\frac{1}{2}}$ (shown by the dashed lines). These results show that to obtain optimum rms noise reduction, relative to $N^{\frac{1}{2}}$, by prefiltering (0.7 - 5.0 cps) and summing the array, the minimum inter-sensor spacing must be approximately three kilometers.

Figures in the original report (No. 221) show the results of the analysis of the noise power spectra for the various combinations of subarrays used to form the unphased sums. In these figures, the power spectra of the unphased sum

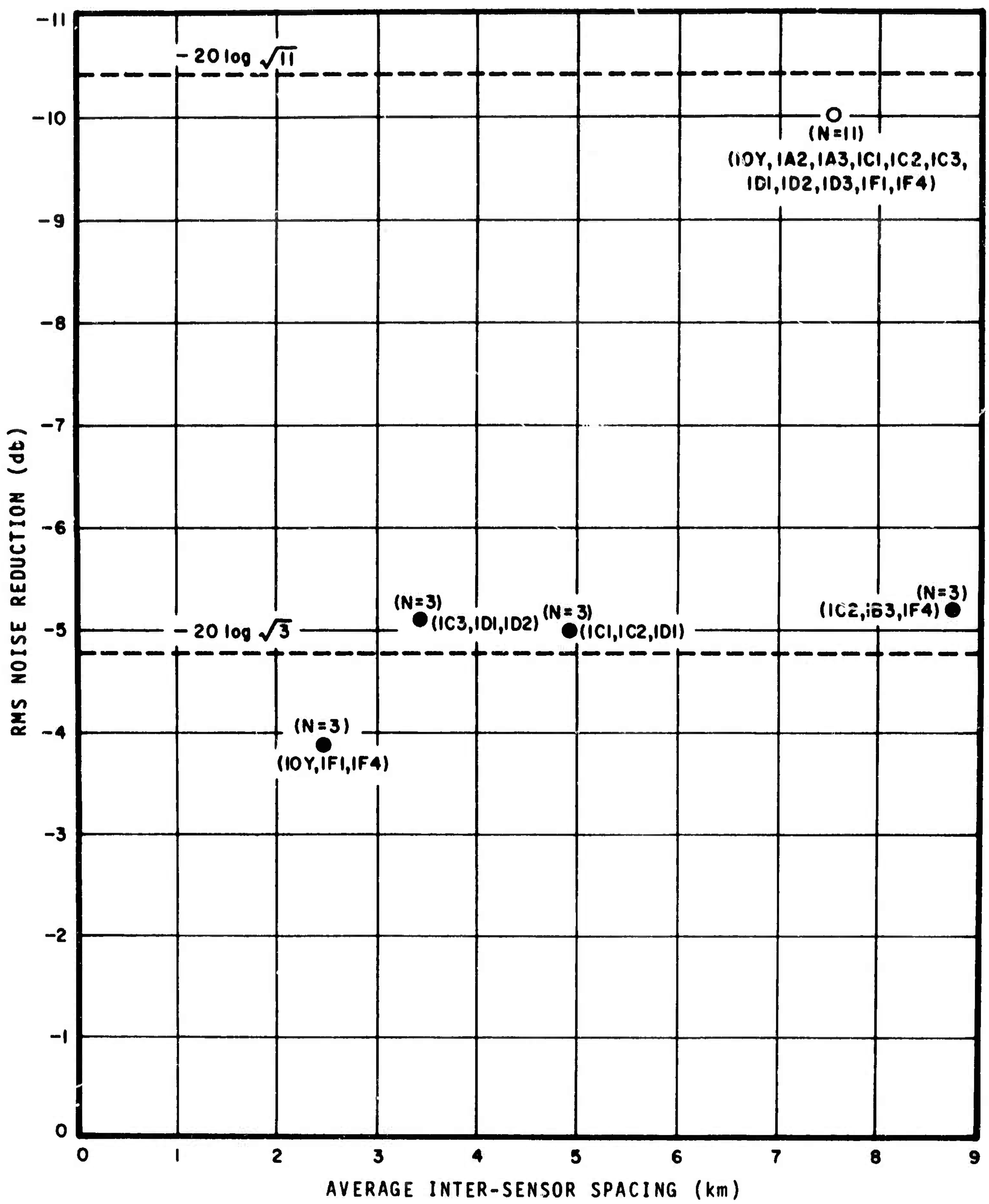

Figure 1. RMS noise reduction by summing various combinations of NORSAR elements

of the noise sample was compared with the average of the spectra from all of the subarrays used to form that sum. These figures show that the spectral shape is essentially the same for both the unphased sum and the average of the individual spectra. The figures also show that, with the exception of the example where the average inter-sensor spacing is only 2.5 km, the unphased sum attenuates the noise at 1 cps, for example, by a factor comparable to $N^{\frac{1}{2}}$. The spectral analyses were performed in all cases on data prefiltered to the band 0.7 - 5.0 cps.

Table 1 summarizes the results of the amplitude analysis of the two teleseismic events under three main headings: Signal, Noise, and S/N. The amount of signal loss, rms noise reduction, and signal-to-noise gain produced by beamforming the array using all 12 elements which were operational at the time the events were recorded is shown under the corresponding heading. As shown in Table 1, the signal loss produced by beamforming the array is less than one db for both events. The rms noise reduction achieved by forming the beams is equal to the $N^{\frac{1}{2}}$ criterion for both events. The signal-to-noise gain from the beamsteered array is attenuated one db relative to $N^{\frac{1}{2}}$ for the two events.

The preliminary evaluation of NORSAR short-period data included an analysis of one signal-free noise sample and the records from two teleseismic events. The following conclusions were based on the results of that study:

1. The minimum inter-sensor spacing required to produce an optimum rms noise reduction, relative to $N^{\frac{1}{2}}$, by prefiltering and summing the array outputs is approximately three kilometers.

2. A signal loss of less than one db is produced in beamforming the array by time-shifting the subarray data using only computed travel-time differences. Part of this signal loss results from using the Fc filter. The remainder of the signal loss is attributed to small misalignment of the P wave and to differences in wave form across the array.

3. In all cases where the average inter-sensor spacing is greater than three kilometers, the rms noise reduction is equivalent to the $N^{\frac{1}{2}}$ criterion. This same noise reduction factor is shown by the power spectra at 1 cps.

Table 1. NORSAR P-wave amplitudes for data prefiltered 0.7 - 5.0 CPS (Fc)

EVENT	DATE	$N^{1/2}_{db}$	SIGNAL			NOISE							S/N						
			m_b		db	m_b		db	m_b		db		S/RANGE			S/RMS			
															db			db	
			MEAN	P-SUM	P-SUM / MEAN	MEAN / RMS	P-SUM / RMS	P-SUM / MEAN / RMS	MEAN / RANGE	P-SUM / RANGE	P-SUM / MEAN / RANGE	MEAN RANGE / RMS	MEAN	P-SUM	P-SUM / MEAN	MEAN	P-SUM	P-SUM / MEAN	
Kuril Is.	04 Feb 68	11	12.45	11.7	-0.6	2.34	0.65	-11	7.11	1.97	-11	3.1	17.8	59.2	+10	53.6	179.0	+10	N=12
Tibet	11 Feb 68	11	36.9	35.0	-0.5	2.09	0.62	-11	6.33	2.23	- 9	3.0	5.9	15.7	+ 9	17.6	55.7	+10	N=12

4. A 3-to-1 ratio of Range-to-RMS is obtained in all cases for a 100-second noise sample.

5. The signal-to-noise ratio produced by the beamformed array is attenuated one db relative to $N^{1/2}$.

Reference

Clark, D.M., 1968, "Preliminary Beamforming Study of the TFO-37 Array", Report No. 216, Seismic Data Laboratory, Teledyne, Inc. Alexandria, Virginia.

B. A Preliminary Evaluation of the Matched Filter Technique in the Detection of Long-Period Body Wave Radiation.

SDL Report No. 222 concerns the detection of long-period body wave radiation for both synthetic and real test cases using the matched filter approach.

To determine the effectiveness of the matched filter technique, we first set up synthetic test cases by burying a known earthquake signal in long-period noise at various S/N ratios. We then used the known earthquake signal as a matched filter. An optimum filter length was determined from the results of this experiment, along with an estimate of the minimum S/N ratio at which the technique breaks down. The results from the synthetic cases were sufficiently encouraging to warrant proceeding the search for long-period body waves from actual events. For actual events the results are less encouraging. We attribute this in part to the lack of sufficient available data from LASA. Only LASA data was considered because it is already in digital format and is best suited for application of array summing techniques.

The first sections of the report deal with the methods and results for the synthetic test cases, and the latter sections deal with the application of the technique to observed data.

The results obtained in this study are mixed. The synthetic test cases show that when the signal used as the filter is identical with the unknown signal, the matched filter technique alone is successful in detecting the unknown signal at a minimum S/N ratio of 4. By beamforming the matched filter

outputs from the nine long-period sensors in the A, E, and F rings at LASA, we were able to detect the presence of the unknown signal at S/N ratios as low as 1. The much poorer performance of the matched filter on observed data may be attributed to differences within the wavetrain of the reference event with respect to the unknown event, and/or the relative absence of long-period body wave radiation from the smaller events.

The matched filter technique worked best on the seismograms from a Kurile Island double event. Using the whole suite of arrivals P through S, we were able to detect both events, the second with an apparent polarity reversal. However, the S/N ratio of the matched filter sum trace for the first event was considerably less than that obtained by straightforward beamforming the band passed seismograms. This suggests that there is considerable mismatch in waveform between the reference signal and the unknown signals, even though the events occurred close together within the same source region. Also, the marked improvement in S/N ratio using the shorter 500-second filter suggests that the mismatch becomes more important when the later phases, particularly S arrivals, are included in the filter. The second event is not easily detected from the individual traces, but after beamforming the matched filter outputs,it is.

Three events recorded on April 1, 1967, had epicenters within 55 km of one another. Furthermore, the epicenters reported by the USC&GS are all at the same depth, the P wave delays across LASA being almost identical. Therefore, the observed signal mismatch is probably due to differences in relative excitation of the various arrivals between the events. Theoretically, we would expect this difference to be greatest for the S wave arrivals. However, we were not able to eliminate the effect of the differences using the level or rectified filters, which suggest that the differences may be more complex than simple variations in amplitude or polarity reversals of the arrivals.

The matched filter results from the December 22, 1966 event were interesting. The focal depth for this event was 77 km. It is located some 350 km from the reference event, although the P wave delays across LASA for the two events are equal to within 0.5 seconds. Using the 730-second filter, which includes the P through SKS arrivals, we were able to detect long-period body wave

radiation at the appropriate times for both P and PcP. This is probably due to the fact that the S-P interval is of very nearly the same duration as the SKS-PcP interval at this particular distance and focal depth. The S/N ratio of the matched filter outputs is low, and without prior knowledge of the expected arrival time it is doubtful whether the onset would have been recognized, particularly using the 500-second filter.

In the case of three events with magnitudes less than 5, we were unable to detect any long-period body wave radiation, either by matched filtering or beamforming. This in part may be due to differences in epicenter location, particularly as they are at different depths from the reference events. However, the partial success of the matched filter on the 77 km deep event suggests that more probably these events radiated only small amounts of energy in the pass band of 10-50 seconds.

The failure of the matched filter below magnitude 5 leads to the question of threshold. Obviously the main problems involved are radiation pattern differences and differences in polarity from one event to another. Relative time shifts of arrivals between the reference event and the unknown event will also tend to degrade the matched filter performance, since the wavetrains no longer match exactly. Differences in radiation pattern result not only in a mismatch of the wavetrains, but also in differences in reported body wave magnitudes. Throughout the report we gave magnitudes based on the USC&GS Bulletin, the North American stations reported in this Bulletin, and the magnitudes reported from LASA. The variation indicates the difficulty in assigning a threshold. Our results (Figure 2) indicate that the threshold for detection is somewhere around $m_b = 5$ for the Kurile Islands in terms of USC&GS magnitudes. It is impossible to express this result in terms of LASA magnitudes since the LASA magnitude (m_b) of the reference event as reported is less than 5.

Finally, we used the portions of the filter between the principle arrivals as our filter in several instances. These intervals are the ones in which PL modes are most likely to occur. We found no evidence that these sections alone improved our ability to detect long-period energy. Nor did simply shortening this interval to bring the principle phases in the

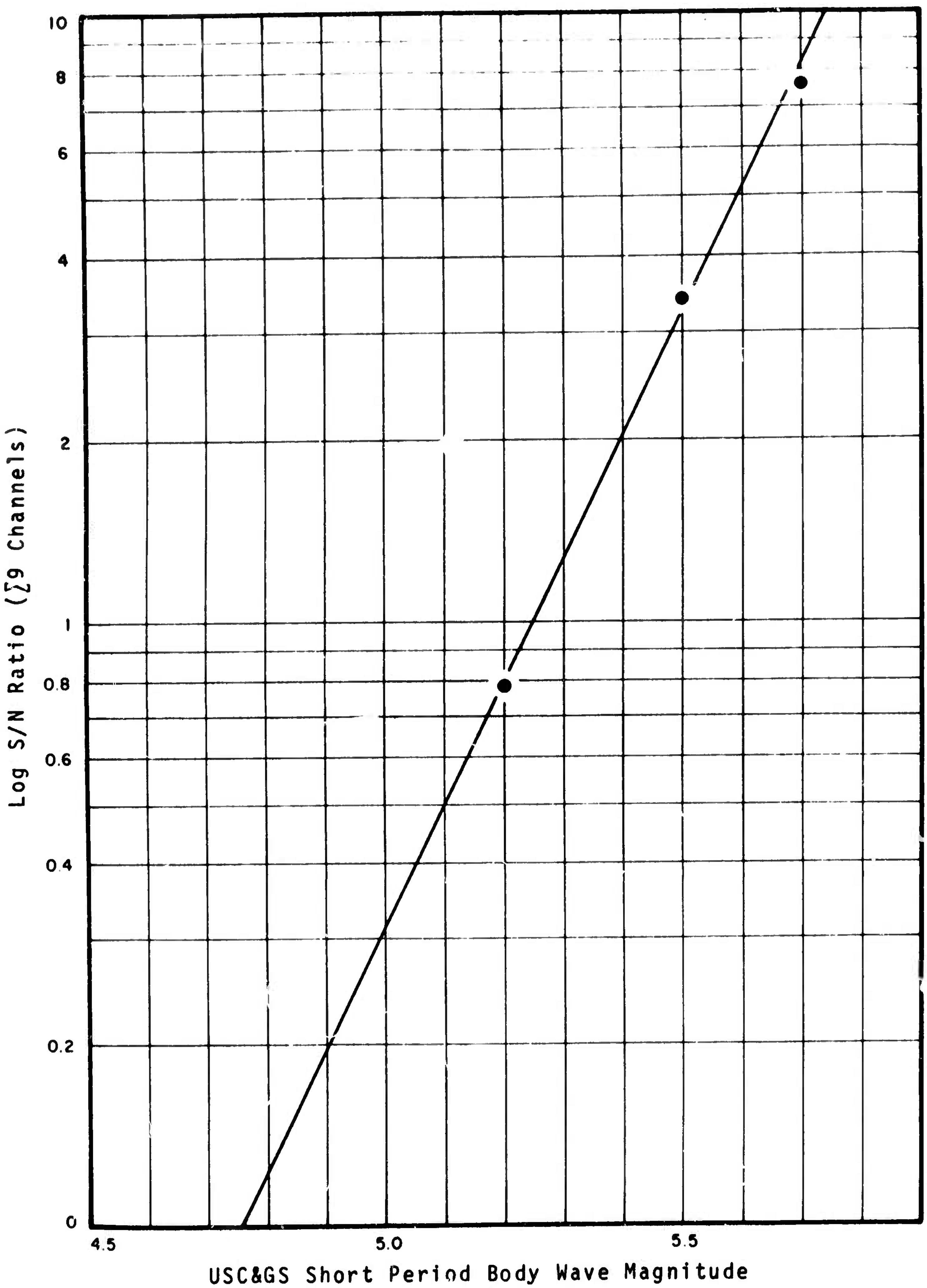

Figure 2. Graph showing S/N ratios obtained by matched filtering as a function of body wave magnitude (m_b)

filter into alignment with the predicted arrival times of the unknown event produce any significant improvement in S/N ratio for the smaller ($m_b \leq 5$) events.

The long-period body wave matched filter technique, although it is not as effective as the surface wave technique in terms of detecting whether or not an event occurred in a particular region, may constitute an important tool for the classification of events. If any long-period body waves are found, their presence would indicate that the event is an earthquake, since long-period teleseismic P waves are seldom observed for explosions. Moreover, the method is cheap in terms of computer time and could be incorporated in an on-line detection system. The ultimate goal should be a system in which, once an event has been detected and located by other means, a long-period body wave matched filter could be quickly and inexpensively applied to determine the presence or absence of long-period body wave radiation.

From the results of this study we conclude:

1. For cases where the unknown signal and the reference signal are very similar in waveform, the matched filter works well.

2. For input S/N ratios less than 4, array summing of the individual match filter outputs is required to observe long-period body wave radiation.

3. Ideally, beamforming the matched filter outputs improves the S/N ratio by a factor of 2 (6 db) over beamforming the band-pass filtered seismograms.

4. Using observed data, the threshold for detection of long-period body waves from events in the Kurile Islands at depths less than 80 km is probably around magnitude 5 (m_b), using 9 elements of LASA. The best results are likely to be obtained when the depth of the reference event and the unknown event are the same.

5. The matched filter technique works best when only the P wave arrivals are used.

6. It would not appear legitimate to include portions of the seismogram after the S arrival time and attribute the output to the presence of long-period body waves, since we know that higher mode surface waves have S wave velocities as an upper bound and may be present in the record anywhere after the S arrival.

7. Despite several attempts to use only "interphase" (PL) portions as a reference filter we found no evidence that using these PL portions of the record alone improved our ability to discern the presence of long-period energy.

8. Amplitude equalization is not an effective means of improving the performance of the matched filter, probably because weaker portions of the reference signal contain noise which we build up by this procedure.

9. Many more events must be analyzed before a reliable threshold for detection of long-period body waves at LASA can be established.

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C. Principles of Wiener Auto-Adaptive Filtering.

SDL Report No. 224 discusses various techniques of designing auto-adaptive (self-changing) filters, and the application of one particular technique to two teleseisms. Also described are the calculation of running correlation functions, using a moving time window, and iterative solutions to the multichannel normal equations. Moreover a listing is included in the original report of a program which will calculate an auto-adaptive multi-channel filter by the use of running correlation functions and the method of steepest descent.

Section III of the report discusses the theory of the mean square error criterion and the application of the principle of orthoganality to multichannel filtering as well as various adaptive filter solutions which depend upon running correlation functions.

A filter whose coefficients depend upon the time-varying statistics of the noise is termed an adaptive filter. A filter which, as the noise statistics change, automatically updates itself without the need of human intervention or supervision is termed an auto-adaptive (self-changing) filter. The auto-adaptive filters used to produce the following results were designed to be linear but time-varying multichannel filters.

Figure 3 is the result of applying the auto-adaptive filter to the LASA input data recorded in subarray D1. The first trace is a timing trace with 1-second pips, every fifth one of which is accentuated. Traces 2 through 11 are the observed data, trace 11 being the one to be predicted; this trace is shifted 1 second to the left. Trace 12 is the output of the auto-adaptive filter. Trace 13 (the error trace) is the difference between trace 11 and trace 12. Trace 14 is the sum of the nine input traces used to predict trace 11. The output of the adaptive filter is seen to be identical to the sum at the start of the record (as it should be, since the initial guess for the filters was 1/N, 0,0,0...).

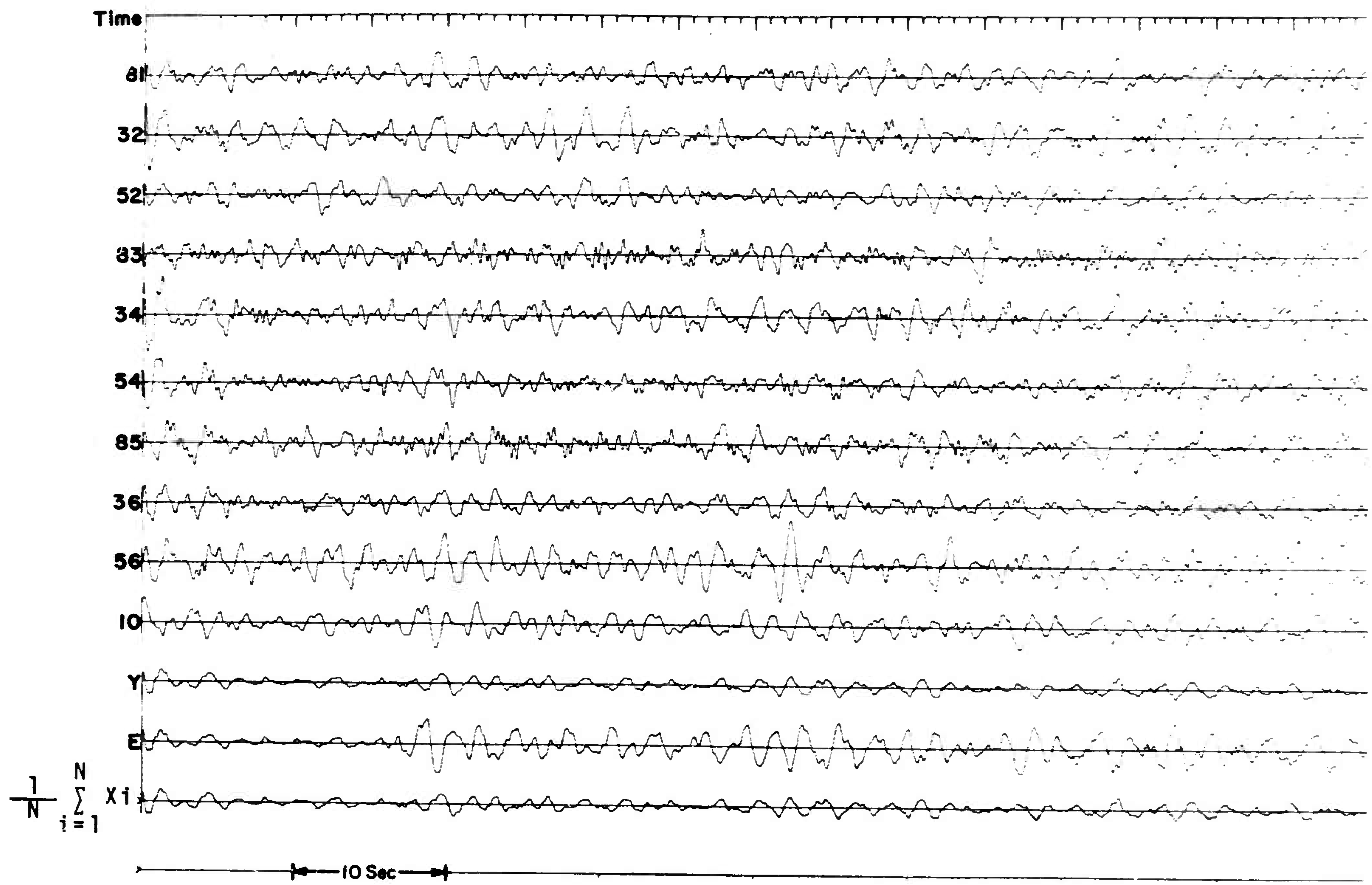

Figure 3. Noise and processed traces before the Aleutian event

Figure 4 is a continutation in time of the same data. We can see that the filter is indeed learning from the input data, since the noise power is getting progressively less in trace 12 as compared to trace 14. In general the same peaks seem to be coming through, but the power is quite a bit less in the output of the adaptive filter (trace 12) as compared to the beamed sum trace (trace 14) as time goes on. Figure 5 is a continuation of the same data which includes the Aleutian event. The first motion of the signal seems to be enhanced as does a secondary phase, probably pP. The signal-to-noise ratio improvement is 2 db over the bandpass phased sum due to some signal rejection by the adaptive filter. The second phase occurs roughly nine seconds after the primary phase, the time delay being about right for pP.

It should be noted that the progressive decrease in the noise power with time is due to two factors: one is the convergence of the adaptive filter from the initial guess toward the optimum time-stationary filter; the other factor is the improvement achieved by reducing time-varying coherent noise. The small improvement (2 db) above the band limited phased sum seems to indicate that the amount of time-varying coherent noise power is low. Of course, another factor to consider is a poor array response which could cause coherent noise to alias back into the main lobe.

From this report we concluded:

1. The method of updating the correlation functions used in this report is a valid method for calculating relatively stable and slowly time varying correlation functions.

2. The auto-adaptive filters designed from the time-varying noise correlation functions do converge, and they yield better results (2 db better on the LASA event) than simple bandpass filtering and beamforming. The concept of auto-adaptive filtering could be applied to single channel (prediction, prediction-error, and deghost) filtering as well as to multichannel filtering.

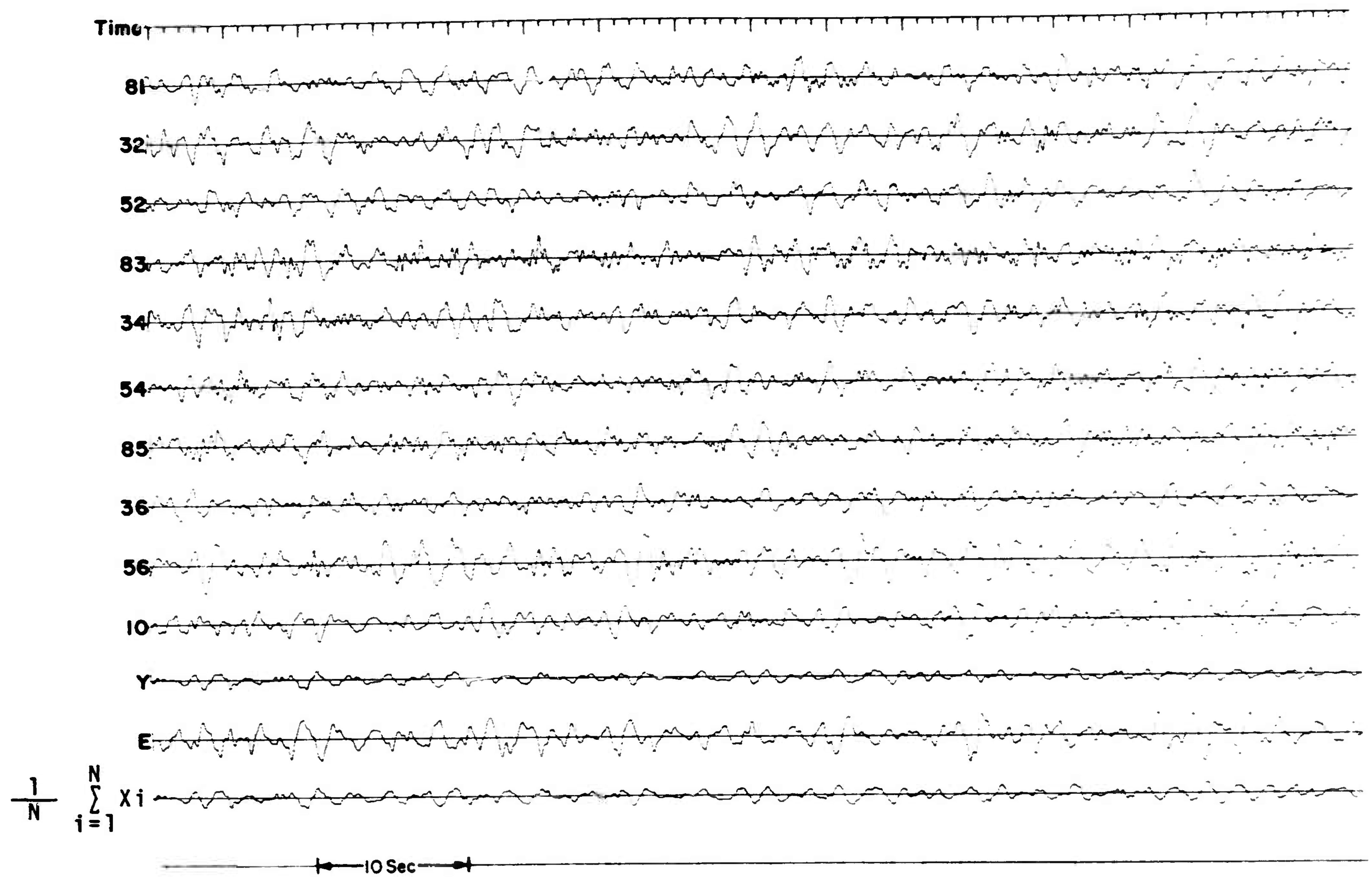

Figure 4. More noise and processed traces before the Aleutian event

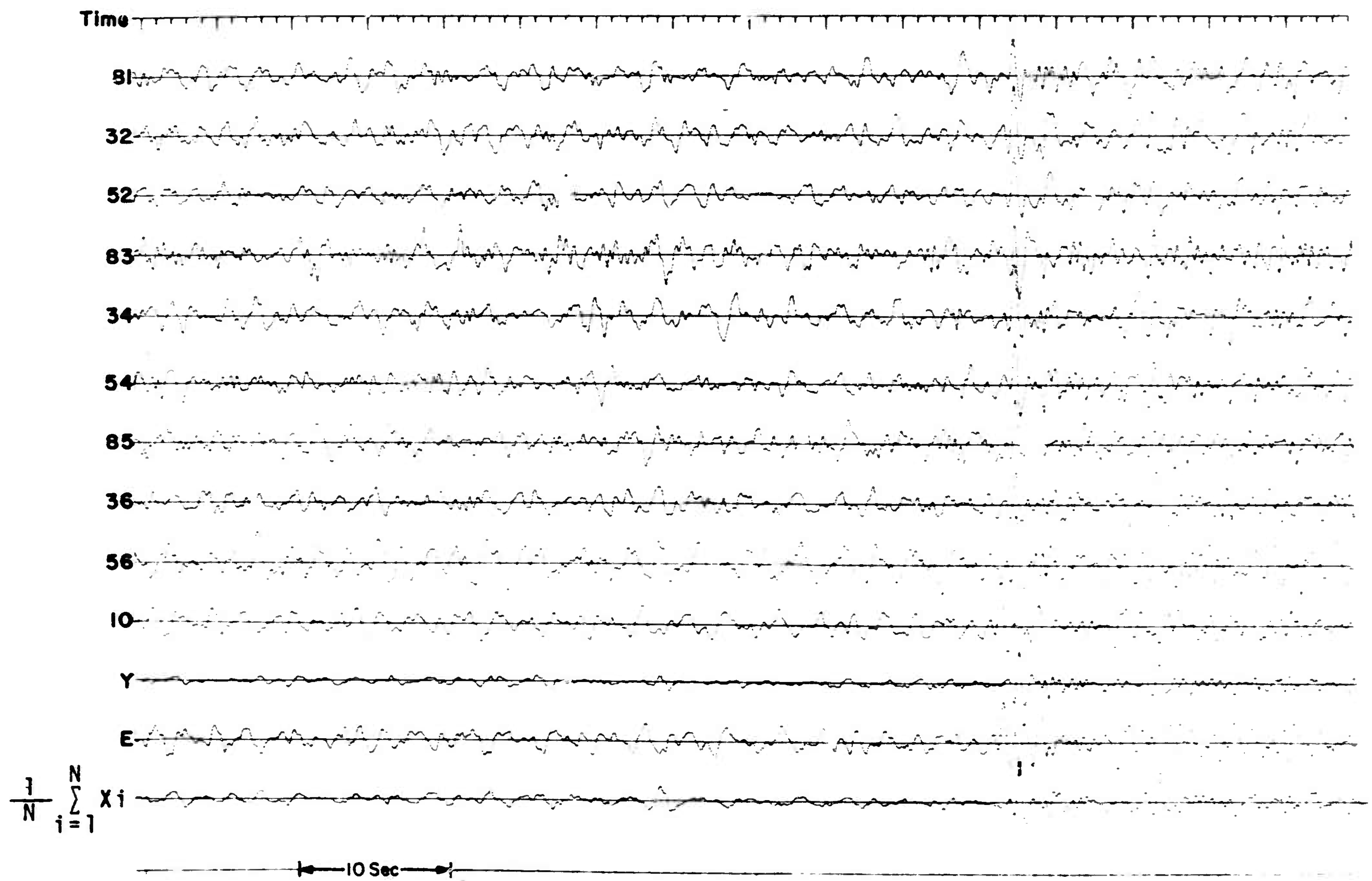

Figure 5. The Aleutian event

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D. Body Wave Magnitude and Source Mechanism

In this study a new method is proposed for improving the body-wave magnitude determination by using the observed values of the body-wave magnitude (m_b) together with the first motion directions, to obtain by least squares analysis the best double couple source parameters; the resulting radiation pattern is then integrated spatially to provide a corrected estimate of the magnitude.

We suggest that a better measure of the "true" body-wave magnitude may be obtained by taking the amplitude of a purely compressional source whose radiation pattern has the same area as the observed radiation pattern.

Naturally, this means that we have to know the source parameters, i.e., the dip direction, dip angle and slip angle of the fault plane and the auxiliary.

To find the source parameters we propose to use data which are readily available, i.e, reported first motion directions together with observed body-wave magnitudes as given by the C&GS Earthquake Data Reports and the ISC Bulletin. Of course, the method is bound to be inaccurate if there are large gaps in the azimuthal coverage, but in this case the other methods also fail. It is hoped that for earthquakes of magnitude 5 and larger, an approximate solution of the source parameters may be obtained and hence a better value of the mean body-wave magnitude may be established. For a detailed mathematical description of the method, the reader is referred to SDL Report No. 225.

Results for a number of events previously studied by other investigators are presented in the original report. For our purpose here, however, the analysis of one event, the Banda Sea Earthquake (21 March 1964), is described.

For this earthquake 37 stations were used, 12 of them with magnitude and 25 with only first motions. Figure 6 shows the observed radiation pattern and Table 2 shows the input data.

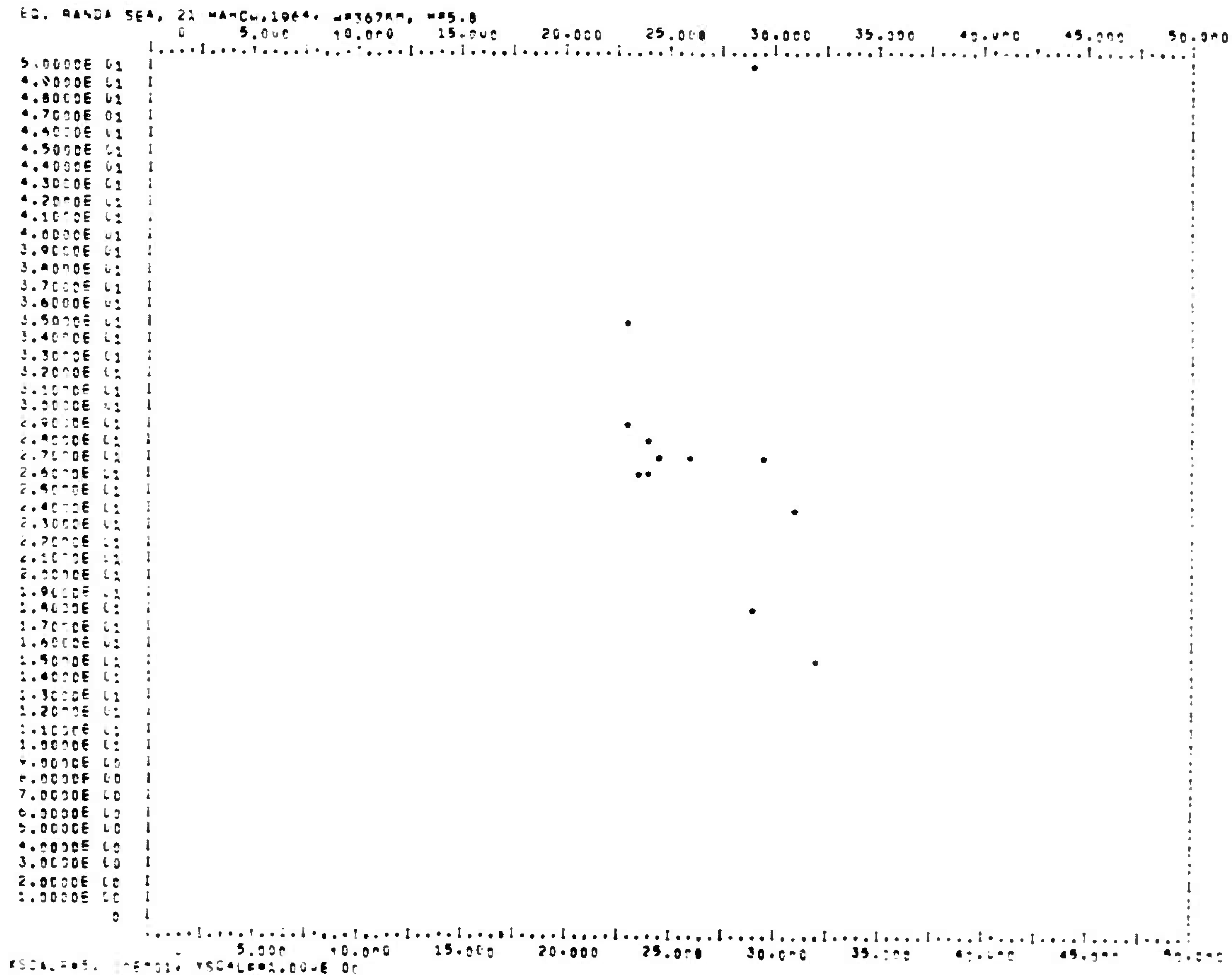

Figure 6. Observed radiation pattern for the Banda Sea earthquake of 21 March 1964

Table 2. Example of input data for the Banda Sea earthquake of 21 March 1964.

EQ. BANDA SEA, 21 MARCH,1964, H=367KM, M=7.8

37	1	367.0	60.0	5.0	5	
I	STA(I)	DIST(I)	TH(I)	AZ(I)	MAG(I)	P+/D-
1	ABU	41.76	138.01	9.00	6.40	-
2	COL	93.34	157.50	25.00	5.30	-
3	KIP	77.62	153.05	67.00	5.70	-
4	PMG	19.23	124.19	100.00	5.80	+
5	RIV	34.70	135.38	145.00	6.10	+
6	CAN	34.65	135.36	149.00	5.90	+
7	NHA	26.20	131.27	315.00	5.30	-
8	NUR	102.13	158.00	330.00	5.20	-
9	KJN	100.25	158.00	334.00	5.70	-
10	KEV	99.86	157.98	340.00	5.50	-
11	BAG	23.85	129.35	342.00	5.30	-
12	ANP	32.05	134.32	349.00	6.00	-
13	MAT	43.79	138.64	12.00	-0	-
14	MTJ	43.91	138.67	14.30	-0	-
15	GUA	26.04	131.12	40.30	-0	-
16	HON	77.56	153.02	66.60	-0	-
17	RAB	24.27	129.77	86.00	-0	-
18	HNR	31.88	134.25	97.50	-0	-
19	AFI	59.71	145.86	102.30	-0	-
20	LUG	39.56	137.30	106.60	-0	+
21	PVC	41.00	137.50	109.70	-0	+
22	KOU	37.96	136.68	115.40	-0	+
23	NOU	40.40	137.62	117.10	-0	+
24	CTA	22.42	127.92	129.10	-0	+
25	BRS	31.53	134.11	134.30	-0	+
26	WEL	54.21	143.18	137.30	-0	+
27	TAU	40.26	137.56	157.80	-0	+
28	ADE	30.13	133.55	162.10	-0	+
29	MUN	27.60	132.11	201.80	-0	+
30	PRE	95.93	157.59	243.30	-0	+
31	BUL	96.48	157.65	248.90	-0	+
32	SHI	80.57	154.23	301.40	-0	-
33	IST	100.82	158.00	310.50	-0	-
34	SHL	47.27	140.13	313.70	-0	-
35	MAN	21.90	127.49	342.10	-0	-
36	HKC	31.53	134.11	335.20	-0	-
37	SEO	43.78	138.63	358.90	-0	-

Figure 7 shows the calculated radiation pattern and Table 3 gives the results in tabular form. In our final solution, 36 stations had the same calculated and observed first motion direction and the one disagreement was a near nodal value. The new mean value of m_b came out to be 5.85 as against the C&GS value of 5.8. The stars in Figure 7 are calculated amplitudes for those stations which had observed values and the dots are calculated amplitudes for those stations which only reported first motion directions.

In conclusion, the comparison of the fault plane solutions obtained by the new method and those obtained using first motions only shows that it is possible to find reasonable agreement. The solution of the Hindu-Kush earthquake parameters show that although better agreement with the first motion directions was obtained by Hedayati and Hirasawa (1966), the amplitude radiation pattern does not agree as well with the observed pattern as that obtained by using a combination of first motion directions together with observed body-wave magnitudes.

The results of the Rat Island earthquake of the 5th of February 1965 show that the proposed method compensates correctly where too many of the observed magnitudes were near to nodes. This shows that the proposed definition of magnitude is superior to taking the arithmetic mean of the observations of m_b.

The fault plane solution found by this method is probably not as accurate as that obtained by S-wave data. However, the new method gives two checks on the accuracy obtained, the first by simply the number of differences in sign between calculated and observed, i.e., the "score". The second is by examining the confidence limits of the magnitude.

The results also indicate that in order to take the radiation pattern into account when finding the "true" value of m_b, it is sufficient to use an approximate solution to the source parameters. This is possible by using readily available magnitude and first motion data without laboriously having to re-examine records.

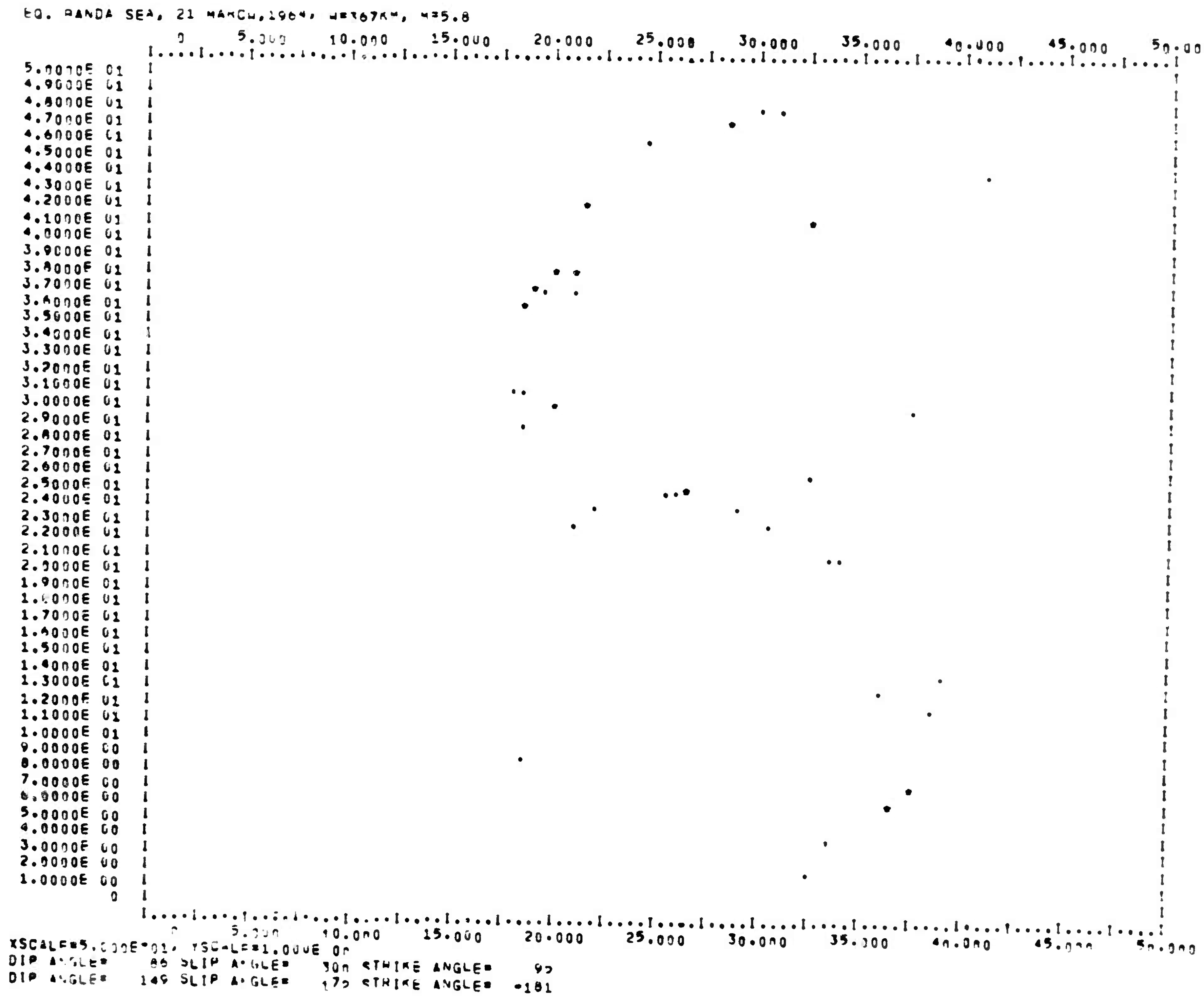

Figure 7. Calculated radiation pattern for the Banda Sea earthquake of 21 March 1964.

Table 3. Results for the Banda Sea earthquake of 21 March 1964.

XK= 2.4467E 02 CONYK= 1.1565E 02 MEAN MAG= 5.85
95 PERCENT CONF. UPPER LIMIT= 6.0
95 PERCENT CONF. LOWER LIMIT= 5.6
SAMPLE VARIANCE= 3.2126E 03

I	STA(I)	AZ(I)	CALC. MAG(I)	C/U	OBS. MAG(I)	C/U
1	ABU	9.0	6.0	-	6.4	-
2	COL	25.0	5.9	-	5.3	-
3	KIP	67.0	5.8	-	5.7	-
4	PMG	100.0	4.9	+	5.8	+
5	RIV	145.0	6.0	+	6.1	+
6	CAN	149.0	6.0	+	5.9	+
7	NHA	315.0	5.5	-	5.3	-
8	NUR	330.0	5.8	-	5.2	-
9	KJN	334.0	5.8	-	5.7	-
10	KEV	340.0	5.8	-	5.5	-
11	BAG	342.0	5.8	-	5.3	-
12	ANP	349.0	5.9	-	6.0	-
13	MAT	12.0	6.1	-	0	-
14	MTJ	14.3	6.1	-	0	-
15	GUA	40.3	6.1	-	0	-
16	HON	66.6	5.8	-	0	-
17	RAB	86.0	5.6	-	0	-
18	HNR	97.5	4.6	-	0	-
19	AFI	102.3	4.5	+	0	-
20	LUG	106.6	5.3	+	0	+
21	PVC	109.7	5.5	+	0	+
22	KOU	115.4	5.6	+	0	+
23	NOU	117.1	5.7	+	0	+
24	CTA	129.1	5.9	+	0	+
25	RRS	134.3	6.0	+	0	+
26	WEL	137.3	5.9	+	0	+
27	TAU	157.6	6.0	+	0	+
28	ADE	162.1	6.1	+	0	+
29	MUN	201.6	5.9	+	0	+
30	PRE	243.3	5.3	+	0	+
31	BUL	248.9	5.2	+	0	+
32	SHI	301.4	5.6	-	0	-
33	IST	310.5	5.6	-	0	-
34	SHL	313.7	5.6	-	0	-
35	MAN	342.1	5.8	-	0	-
36	HKC	335.2	5.8	-	0	-
37	SEO	358.9	6.0	-	0	-

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E. Earthquake and Explosion Analysis.

Projects completed include photo albums for four events and travel-time computations for NTS and other sites. In addition complexities were computed for a number of special events.

III. SUPPORT AND SERVICE TASKS

A. VELA-Uniform Data Services

As part of the contract work statement, the SDL provided one or more of the following support and service functions for VSC and other VELA participants:

- copies of 16 and 35 mm film
- playouts of earthquakes and special events
- copies of composite analog tapes
- composite analog tapes of special events
- use of 1604 computer for checking out new programs or running production programs
- copies of digital programs
- digitized data in standard formats or special formats for use on computers other than the 1604.
- running SDL production programs, such as power spectral density and array processing on specified data.
- digital x-y plots of power spectra or digitized data
- signal reproduction booklets
- space for visiting scientists utilizing SDL facilities to study data and exchange information with SDL personnel.

During this report period, 51 such projects were completed and the 10 organizations receiving these services are listed in Appendix A.

B. Data Library

The data library contains approximately 8345 digitized seismograms, 246 digital computer programs and 306 composite analog magnetic tapes, all available for use by the VELA-Uniform program.

The following additions were made during this period:

1. Digital Seismograms - 215 including

   - data from three explosions
   - eight earthquakes recorded at various stations

2. LASA Data - 30 tapes

   - there are a total of 1438 digital tapes in the library including 1034 field tapes. There is also a master calibration tape which contains the magnification (digital counts per millimicron) of each sensor for every subarray. These magnifications have been computed for all calibration tapes currently in house. As each new calibration is received, it is routinely run through the new program CALIBR and added to the master tape.

3. Digital Programs - 9 including

MAPRINT - This program works with output produced by the NETWORK3 program on a BCD magnetic tape. The NETWORK3 produces up to 9 different probability or magnitude values for each event of the given set of events. The purpose of MAPRINT is to print these values so that a specific map may be overlayed and the values contoured. Up to 9 different maps may be printed corresponding to the nine different values per event. Each map contains all events and they have the same overlay.

ARRAYTAB - Generates tape reel 114 which contains the coordinates of array sensors relative to the center of the array.

SUB2LIB - Uses all channels on a subset tape to generate an unpacked library format tape and a listing of the label information.

DIFFER - Despikes seismograms written in the SDL SUBSET format.

WHITE - Finds a filter from a selected time interval of the first trace of a seismogram and uses it to filter all traces of that seismogram over another selected time interval.

HRVKSPEC - Computes the high-resolution wavenumber spectrum of seismic linear-array time series data. The high-resolution wavenumber spectrum may be calculated with respect to a particular sensor in the array, or it may be averaged over all of the sensors in the array.

GEODIST - Given a reference point, GEODIST computes the distance (in both km and degs), azimuth, and back azimuth to each point in an array of secondary points using Rudoe's method supplied by Mr. Paul Thomas of NRL.

NETMEV(modified) - This is a modification of NETWORK2 which is designed to produce an output tape containing event locations and selected stations to be processed by the program LOCMEV.

LSTSQELP - Finds the least squares fit to a set of input points and computes a confidence ellipse on the slope and intercept of the solution.

4. Analog Composite Tapes - 7 including

   a. Made by SDL

      SCROLL
      FAULTLESS
      KNICKERBOCKER
      PIN STRIPE

b. Made by Geotech

SHUFFLE
BOXCAR
CHATEAIGAY

C. Data Compression

This is a continuing routine operation, and production is maintained at the level needed to meet the requirements of the field operation (LRSM and U.S. Observatories) and the Seismic Data Laboratory. For this period 1728 tapes were compressed.

D. Automated Bulletin Process

The July 1968 Observatory Bulletin was processed during this report period and forwarded to Geotech, a Teledyne Company, for checking and publication.

APPENDIX A

July - September 1968

Organizations Receiving SDL Data Services

Massachusetts Institute of Technology
University of Washington
Texas Instruments, Inc.
St. Louis University
Missile Electronic Warfare Technical Area, New Mexico
UCLA
Pennsylvania State University
Air Force Office of Scientific Research
Vitro
General Atronics Corporation

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10. AVAILABILITY/LIMITATION NOTICES

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of Chief, AFTAC.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY ADVANCED RESEARCH PROJECTS AGENCY NUCLEAR TEST DETECTION OFFICE WASHINGTON, D. C.

13. ABSTRACT

This report summarizes the work done by the SDL during the period July through September 1968, and is primarily concerned with seismic research activities related to the detection and identification of nuclear explosions and earthquake phenomenon. Also discussed are the support tasks and data services performed for other participants in the VELA-Uniform project.

14. KEY WORDS

Matched filtering	Seismic magnitude	NORSAR
Long-period body-wave radiation	Seismic travel-time	
Detection	Seismic amplitude	
LASA	VELA-Uniform	
	Nuclear Tests	

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